

*Report on the Total Solar Eclipse of 1911, April 28. (Observed
by the Expedition of the Joint Permanent Eclipse Committee
to Vavau, Tonga Islands, South Pacific.)*

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[PLATE 10.]

1. *General Arrangements.*

The expedition to observe the total solar eclipse of 1911, April 28, was organised by the Joint Permanent Eclipse Committee, the expenses being defrayed by the Government Grant Fund. Of the few islands in the South Pacific crossed by the track of the moon's shadow during totality, Vavau, one of the northernmost group of the Tonga or Friendly Islands, was the most suitable for observing the eclipse, the duration of totality being computed at 217 seconds, and there being a reasonable prospect of good weather. The programme of observations consisted of photographs of the corona on a large and relatively small scale for coronal detail and extension of the streamers, and photographs of the spectrum of the corona and of the lower chromosphere. For these purposes the expedition was furnished with a 4-inch photographic lens of 20 feet focal length, kindly lent by the Council of the Royal Irish Academy, and the 4-inch Dallmeyer "Abney" lens of 34 inches focal length. For the spectrum of the corona Prof. Newall kindly lent the quartz spectroscope of four prisms, presented to the Cambridge Observatory by Major Hills, in order further to investigate the ultra-violet spectrum. The fourth instrument was made up of a large 7-inch prism of 40° in combination with a 6-inch Dallmeyer portrait lens of 30 inches focal length. This objective prismatic camera gave a short but very bright spectrum, 4.5 cm. from H_α to H_γ . The intention was to investigate the red end of the coronal spectrum on dyed plates, and incidentally to photograph the flash spectrum.

The members of the expedition were Father Cortie and Mr. W. McKeon, from the Stonyhurst College Observatory, and Father E. Pigot, Director of the Observatory of St. Ignatius' College, Riverview, Sydney, N.S.W., who also acted as agent for the expedition in Sydney, in the preparation of huts to cover the instruments, and in the gathering of materials for building the piers for the foundations. The Admiralty gave instructions that

H.M.S. "Encounter" should convey the observers and the instruments from Sydney to Vavau and back, and that every assistance should be rendered to the expedition in the erection of the instruments and in the observations. The expedition is greatly indebted to Captain Colomb, and to the officers and men of the "Encounter," for their enthusiastic co-operation in the work of the expedition.

The Stonyhurst observers left Tilbury, with the instruments, on board the Orient Line R.M.S. "Otway," on February 3, and arrived at Sydney on March 16. The "Encounter" sailed from Sydney on March 25 and arrived at Vavau on April 2.

2. *Erection of Instruments.*

All the cases containing the instruments were landed ashore by April 5, and a clearing was made of dense undergrowth and of some coconut palm trees on the space reserved as a coaling ground by the Admiralty. The co-ordinates of the observing station are approximately longitude $173^{\circ} 59' 4''$ W., latitude $18^{\circ} 40' 5''$ S. Two expeditions, namely, that organised by the Joint Permanent Committee, and that from the Solar Physics Observatory under the leadership of Dr. Lockyer, occupied adjoining stations, and we are considerably indebted to Mr. Brooks, of Dr. Lockyer's party, for determining the meridian of all our instruments. Fortunately the weather remained fine until the evening of April 10, by which date the sailors had cleared the ground, had made concrete bases for the mounting of the cœlostats, and had assisted in the considerable progress which had been made in the erection of the instruments. After that date, until and including the day of the eclipse, the weather was broken, with at times torrential showers of tropical rain.

The Coronagraphs.—These two instruments of long and short focal length were mounted side by side, horizontally, so that the prolongations of their axes were in the azimuth of sunset, $14^{\circ} 47'$ N. of W., the azimuth of the sun at totality being 49° E. of N., and its altitude 43° . Exact focussing was secured by a series of photographs of sunspots taken during the days preceding the eclipse. The best images in the 20-foot coronagraph were secured with a diameter of the sun's image of $2\frac{1}{16}$ inches. The camera body was made in sections of zinc, gradually increasing in cross-section so as to fit a camera bellows with rack-and-pinion adjustment, carrying plate-holders 10×8 inches. For stability the camera was mounted on a long trestle table, secured by battens, the ends of the trestles being sunk several inches in the ground. Deformation of the images on the ground-glass screen was caused by convection currents, due to unequal heating of the sections of the long zinc

tube. This was altogether remedied by protecting the whole instrument from the direct rays of the sun by a roofing of palm-leaf thatch, and by hanging matting from the flat roof on the sunward side. In addition the lens end of the camera had a double awning over it. Fortunately, the soil was a rich loam without any dust, and as the centres of the lenses were raised 4 feet 3 inches above the level of the ground, and the ground was covered with loose palm leaves, the effect of radiation from the ground was practically eliminated. The two coronagraphs were supplied with light from the mirror of a 16-inch cœlostast, mounted solidly on a box filled with coral and earth, which was itself mounted on a concrete pier. The driving clock stood on a separate pillar. One weight of $24\frac{1}{2}$ lb. sufficed to drive it, the position of fall on a tall upright, which corresponded to the best rate, being found by repeated experiments. The cœlostast was placed in position and its polar axis adjusted for latitude by the ordinary methods, frequently described in former eclipse reports. An Abney level is a most useful adjunct to the instrument, especially so in cases when there is no attached theodolite. The 20-foot coronagraph was under the charge of Mr. W. McKeon, S.J., assisted by Mr. Baker, gunner, who made the exposures, and three stokers to hand and take plate-holders, and to record exposure times. Lieutenant Elmsley operated the 34-inch coronagraph, and he was assisted by four stokers. The 16-inch cœlostast was under the charge of Chief Engine-room Artificer Langhorn, who spent much time in remedying defects in the instrument, in contriving mechanical devices for its stability, and in regulating the clock. The following programmes for exposures during totality were carried out.

The 20-foot Coronagraph.

Number of slide.	Plate.	Speed number (H. and D.).	Time by eclipse clock.	Exposure.	Result.
1	f.g.o.	50	217—215	secs. 2	Blank.
2	f.g.o.	50	200—195	5	"
3	n.f.	200	185—170	15	"
4	n.f.	200	160—140	20	"
5	n.f.	200	130—80	50	"
6	n.f.	200	65—40	25	Weak impression.
7	f.g.o.	50	30—25	5	" "
8	f.g.o.	50	15—13	2	" "

The 34-inch Coronagraph.

Number of slide.	Plate.	Speed number (H. and D.).	Time by Eclipse clock.	Exposure.	Result.
				secs.	
1	f.g.o.	50	217—215	2	Faintest impression.
2	f.g.o.	50	200—196	4	" "
3	n.f.	200	180—165	15	Blank.
4	n.f.	200	150—130	20	" "
5	n.f.	200	115—75	40	Faint impression.
6	n.f.	200	65—40	25	Strong impression.
7	f.g.o.	50	30—24	6	Faintest impression.
8	f.g.o.	50	10—7	3	Faint impression after totality.

The letters f.g.o. stand for Imperial fine grain ordinary plate, and n.f. for Imperial orthochromatic non-filter plate. For the purpose of orientation a double exposure of the partial eclipse was made on a single plate shortly after totality.

The Prismatic Camera and Associated Instruments.—These instruments were under the charge of Father Pigot, who was assisted by Engineer-Lieutenant McEwan, who operated the exposures for the prismatic camera, Chief Petty Officer Reid, three stokers and one seaman. Father Pigot determined the deviation by the prism at H_β when placed horizontally to be approximately $28^\circ 5'$. Dr. Crommelin had kindly worked out that the point of second contact on the sun's image seen in the cœlostæt mirror was $34^\circ 45'$ to the left of the vertex, when viewed from the side away from the cœlostæt, and the corresponding position of third contact 171° to the right of the vertex. These positions would have been extremely awkward for obtaining symmetrical and concentric arcs in the flash spectrum. The instrument was therefore rigidly fixed to the top of a table, the legs of which were sunk in the ground, and tilted through an angle of 55° . This was effected by hinging the lid of the table and lifting the further edge by means of two iron rods with rough screw adjustment. This diminished the deviation at H_β by the cosine of the angle of tilt, so that it was reduced to $16^\circ 28'$. The azimuth of the axis of the telescope, owing to the deviation of the prism, was $13^\circ 6'$ N. of W. Two subsidiary instruments were placed on the tilted lid of the table, a grating camera made up of a Thorp replica 2×1.5 inches ruled surface, 14,438 lines to the inch, placed in front of the front combination of a portrait lens 2.3 inches clear aperture and 30 inches focal length; and a Hilger one-prism spectroscope, the prism being replaced by a similar Thorp transmission grating. The image of the sun was focussed on the slit of this latter instrument by means of a long-focus telescope lens lent by the captain of the "Encounter." Its function was intended to be to give independent

signals for the flash spectrum at the beginning and end of totality. Besides exposures on the flash spectra, three exposures for the spectrum of the corona were planned on Wratten and Wainwright's panchromatic plates, the first for 30 seconds from count 205 to 175 seconds, the second of 90 seconds at mid-eclipse from 170 to 80, and the third of 55 seconds from 75 to 20. A 12-inch cœlostat, under the charge of Chief Engine-room Artificer Firth, supplied a beam of light to the three instruments. The whole installation was conveniently covered by a tent, 12×6 feet, rising 8 feet 2 inches to the top of the gable. Waterproof material hung in sections over it, and the flaps could be raised when observations had to be made.

The Quartz Spectroscope.—This instrument has been freely described in the eclipse reports of former observers. The adjustments finally adopted, after considerable preliminary experimental work at Stonyhurst, were substantially the same as those made by Dr. Dyson in Sumatra in the eclipse of 1901,* except that the prisms were at minimum deviation at $\lambda 3570$. The object glass was focussed for $\lambda 3400$ approximately, and the image on the slit, visually out of focus, was viewed by an opal glass kindly lent by Dr. Dyson. The spectrum was in good focus for about three inches from $\lambda 4000$ to $\lambda 3300$. The light was supplied by a 12-inch silver-on-glass mirror mounted in the meridian as a heliostat. As silver absorbs violet light a speculum-metal mirror would have been preferable. The spectroscope was placed horizontally on a table, and the quartz 5-inch object glass on a tripod stand. The whole instrument was covered by a tent similar in construction to that described above. Father Cortie took charge of the instrument, assisted by Mr. Bright, torpedo gunner, to whom was entrusted the delicate operation of placing the sun's image in the proper positions on the slit for the first and second flash, and for the coronal spectrum, on which one long exposure was to be made. Three stokers also assisted, and the heliostat was under the charge of Stoker Petty Officer Ash. Unfortunately, clouds spoiled all the exposures on the day of the eclipse. There is nothing on the plates, except an impression of continuous spectrum at second contact. Even had the weather been fine, the atmosphere was so humid that it is doubtful whether there would have been many ultra-violet lines recorded. Frequent drills for all the observers were held on the five days preceding the eclipse, under the general command of Captain Colomb.

3. *Day of the Eclipse and After.*

The fine weather of our first week at Vavau gave place on April 10 to broken weather with heavy showers nearly every day. The mornings were

* 'Roy. Soc. Proc.,' vol. 69, p. 245.

generally fine at about the time of eclipse. On April 26 a fresh S.E. breeze brought up a new development, in the formation of thick and extensive cirrus clouds. On April 28 (we reckoned the civil day by Sydney time) there was much cloudiness, which persisted during the night, and into the early morning of the 29th. The sky cleared just before first contact, and remained beautifully clear, with, however, passing cumuli, during the earlier phases of the partial eclipse. As totality approached dense cirro-stratus formed over the partially eclipsed sun. These clouds were purely local, as going north the weather conditions improved, being good for M. Stefanik at the Catholic Mission compound; better for the Australians in their camp near Neiafu, and best for Mr. Worthington, removed some 500 yards from the Australians. From the deck of the s.s. "Boveric," anchored off the wharf at Neiafu, some two miles distant, a perfect view of the eclipse was obtained. The local clouds at the British station were due to the fall in temperature, and the consequent condensation of the aqueous vapour, conditioned by the proximity of an eminence which deflected the wind and prevented it blowing the clouds away. The total phase commenced about 20 seconds before the predicted time, an experience which was corroborated at the Australian station. The clouds cleared somewhat towards the end of totality, some 90 seconds approximately. Through a veil of thin cirrus a typically minimum corona appeared, the extension being greatest in the N.E. quadrant, and of about one lunar diameter. Around the moon's limb was a bright ring, which would have been very bright in a clear sky. Just before the sun's limb appeared, a beautiful red prominence was seen, almost at the exact angle of third contact from the N. point, which shone out like a vivid glow lamp. During totality the light scattered by the clouds rendered the use of lamps unnecessary. A loud chorus of chirping crickets, as at the approach of nightfall, was raised and continued during totality. A Kanaka gave a howl and ran away frightened into the bush. But there was no noise from the Tongans, the native governor having considerably given orders that silence was to be maintained, and that no fires were to be lighted so that there should be no smoke. Mr. McKeon commenced developing the plates the same night, when it was comparatively cool, at the Catholic Mission School. But as the conditions for working were not very satisfactory, the plates still undeveloped were kindly finished on the following night by Mr. Baker, the official photographer of the Australian expedition. The instruments were all dismounted and packed on board the "Encounter" by May 2, and we sailed for Suva, Fiji, on the 4th, arriving May 6. We sailed for Sydney on May 11, which was reached on the 17th. Commander Mellor, who had been indefatigable in all arrangements with regard to the

expedition, superintended the landing of the instruments. They were transhipped to the Orient liner "Orontes," which sailed from Sydney on June 10 and arrived at Tilbury, July 23.

4. *Results.*

Under the untoward circumstances narrated above the results obtained are very meagre. With the 20-foot coronagraph two plates show the lower corona in the immediate neighbourhood of the moon's periphery. The first was exposed from 45 to 20 seconds, approximately, before the end of totality, the allowance being 20 seconds difference from the recorded time, and the second from 10 to 5 seconds. There is a very fine bank of prominences from position angle 240° to 258° on the latter photograph, covering the position of third contact. Several other small prominences appear on the two plates. The following are the angles:—

Number.	Plate 6.	Plate 7.
1	189°	$187-192^{\circ}$
2	210	210
3	213	
4	247	240
5	254	} 258
6	256	
7	261	
8	287	288
9	299	300

In addition, both plates show a distinct brightening in the lower corona at position angle 50° on the E. limb, evidently the base of a bright streamer. With the 34-inch coronagraph one fairly good impression of the corona was obtained, on a plate exposed between 45—20 seconds before third contact. On this photograph the corona extends about one-half a lunar diameter on the E. limb, and barely that extent on the W. limb. The lower corona is very bright, and several polar rays are discernible. A reproduction of the photograph appears with this report (Plate 10).

Only one of the exposures for the spectrum is of any value, and that was secured just before, and at the time of, the second flash, with the prismatic camera. The plate was to have been exposed from 75 to 20 seconds for the coronal spectrum; it was really exposed, owing to the eclipse beginning before the predicted time, from 55 to the end of totality, and so caught the second flash. The hydrogen series from H_{α} to H_{δ} is impressed on the plate, on a strong continuous background which extends between the approximate limits $\lambda 7065$ and $\lambda 3700$, the portion from the red end to the K line being

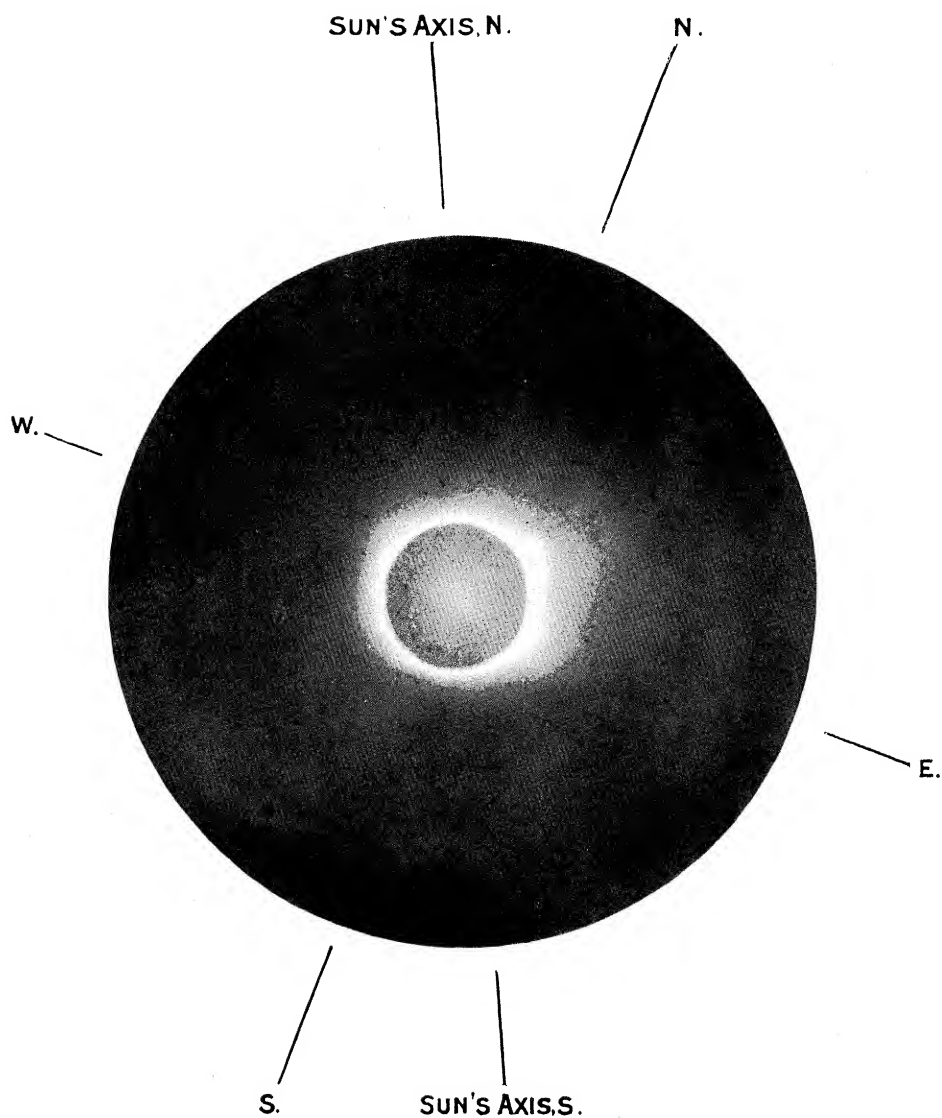
in good focus. It is a very dense negative and it is difficult to make measures on it. There are seven lines beyond H_{α} in the red, including the two helium lines $\lambda 7065.5$ and $\lambda 6673.3$, and about twenty other lines between H_{α} and H_{β} . Under the conditions of exposure these may be taken to be the strongest lines in the chromospheric spectrum. There is a suspicion also of the presence of some purely coronal lines. This plate will receive a more careful examination later on.

5. *Conclusions.*

The corona of 1911 was of a markedly minimum type, flattened at the poles, and with the wings confined to middle solar latitudes. It occurred at a period of very low spot activity, the mean daily disc area of sunspots, in terms of the $1/5000$ of the visible surface, being for the year, from the Stonyhurst drawings, 0.3 ; a drop of over 83 per cent. on the number for the preceding year. The month of April was by far the most active of the year, the mean daily number rising to 1.3 . The actual maximum area of spotted surface for the year occurred on the day, and the day preceding the eclipse. The spots furnishing this area were on or near the central meridian on the day of eclipse. Had they been near the limbs, it is not unlikely that arches would have been seen in the lower corona as in 1901. But, in fact, it was absolutely uniform, without any structure whatsoever. Although the eclipse took place in a year of very few sunspots, yet the actual minimum was probably about a year later. A considerable and sympathetic reduction in prominence activity had also occurred, and prominences in high latitudes were practically non-existent. Mr. Newbegin's results* for prominence observations indicate "that the points in latitude mainly affected were between 50° N. and 50° S., and more particularly between 30° and 50° S." These regions are precisely those marked by the two main wings constituting the "feather" of the "wind-vane" on the E. side of the solar corona. The brightening at about 50° N. on one of the plates has already been noticed. A close connection between the streamers of the solar corona and the regions of prominence activity has often been suggested by eclipse photographs.

The position angle of the N. end of the sun's axis on the day of the eclipse was $24^{\circ} 50'$ W. of the N. point. The solar corona is symmetrical about the axis. There is, too, a great similarity between the photographs of the corona: 1878, July 29; 1889, January 1; 1889, December 21; 1900, May 28; and 1911, April 28. All are of the "wind-vane" type, associated with minimum periods of solar spot and prominence activity, but, if the

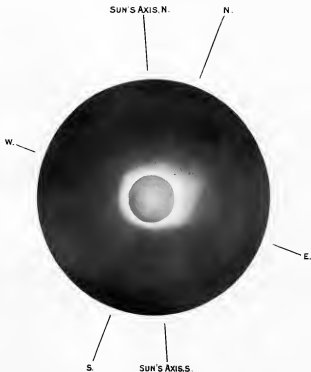
* 'Journal B.A.A.,' vol. 22, p. 5.



Photograph of Corona, obtained with Dallmeyer Rapid Rectilinear Lens of 4 inches aperture.
Exposure 25 seconds through clouds. Twofold enlargement.

photographs be compared among themselves, it will be noted that the arrow of the vane points E. and the feather W. in those of 1878, 1889, and 1900, whereas the direction is reversed in the eclipse of 1911.

We cannot conclude without recording with thanks the kind offices of the Astronomer Royal, Dr. Crommelin, Vice-Admiral Mostyn Field, and Prof. Newall, on behalf of the expedition. Thanks are also due to Prof. Newall and the Council of the Royal Irish Academy for the loan of instruments, and to Dr. Lockyer, Mr. F. McClean, and Mr. Brooks, for much kind assistance. In Australia, Father Pigot, Mr. J. Nangle, and Mr. Baracchi were most active in furthering the ends of the expedition, and much kind hospitality and assistance was rendered at Vavau by Fathers Macé and Deguerry. We are greatly indebted to Captain Colomb, Commander Mellor, and the officers and crew of H.M.S. "Encounter," for their valuable assistance, and, in particular, to Lieutenant Elmsley, Engineer-Lieutenant McEwan, and to Mr. Bright, Mr. Baker, and Mr. Head, our own particular assistants. We cannot fail to recognise the kind courtesy of the Orient Steamship Company in carrying our instrumental outfit free of charge, and the ready assistance of the captains and officers of the "Otway" and "Orontes" in the careful landing of the instruments.



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